Sources and Transport of Air Pollution from Ships: Current Understanding, Implications, and Trends

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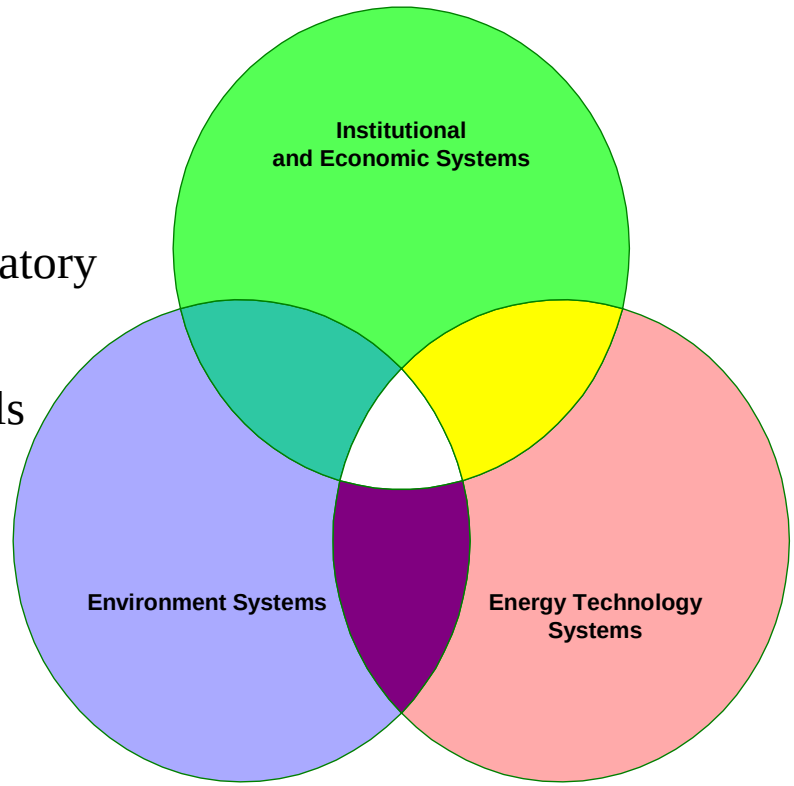
Marine Transportation System

Recognized as a system of systems

MTS Critical Issues

- Safety
  - vessel operations
  - infrastructure
- Competitiveness
  - MTS technologies
  - labor
- National Security
  - crime and terrorism
  - deployment
- Infrastructure
  - capacity issues
  - funding and regulatory
- Environmental
  - ports and terminals
  - ships
  - dredging



Maritime Transportation is vital component of international trade

- U.S. waterways move 2.1 Billion tonne-km
  - Relative share of cargo by water is 22% to 24%
  - Truck, rail account for 25% to 29% in U.S.
  - 67% of consumer goods move by water
  - 95% of all trade tonnage moves by ship

- Globally, more than 13 Billion tonne-km moved by 35,000 oceangoing ships

Energy and environment questions facing the maritime industry today...

(1) How can the MTS meet growing trade and mobility demands while mitigating energy and environmental consequences?

(2) What is the MTS contribution to air quality problems and how to improve this?

(3) What is the potential for shipping to reduce greenhouse gas emissions?

Complex System

- Tug and towboats
  - 1-30 barges: .5-4 MW
- High speed ferries
  - 150-350 passengers: 2-4 MW
- Roll-on\Roll-off
  - 200-600 vehicles: 15-25 MW
- Tankers
  - 250,000 tons of oil: 25-35 MW
- Container
  - 1750 TEU: 20-25 MW
  - 4300TEU: 35-45 MW
  - 6000 TEU: 55-65 MW

Ship Emissions Overview

- Cargo ships produce ~70% of emissions
- Ships are natural leaders in fuel economy, resulting in lower CO_2 per cargo-mile
- Last unregulated source for traditional air pollutants (SOx, PM, NOx)
  - Residual fuels result in higher emissions of particulate matter (PM) and sulfur oxides (SOx)
  - Marine diesel engines emit more NOx, contributing to regional air pollution

The goal is to achieve win-win reductions

Maritime Transportation and Emissions: Evolving Consensus

Previous views about ship emissions:	Current understanding:
2% of CO_2 therefore not significant	14% of NOx, 5% of SOx, 2% of CO_2 from fossil fuel
Offshore, so no impact	Nearshore and long range impacts
Difficult to control	Feasible technologies at reasonable costs
	Policy needed

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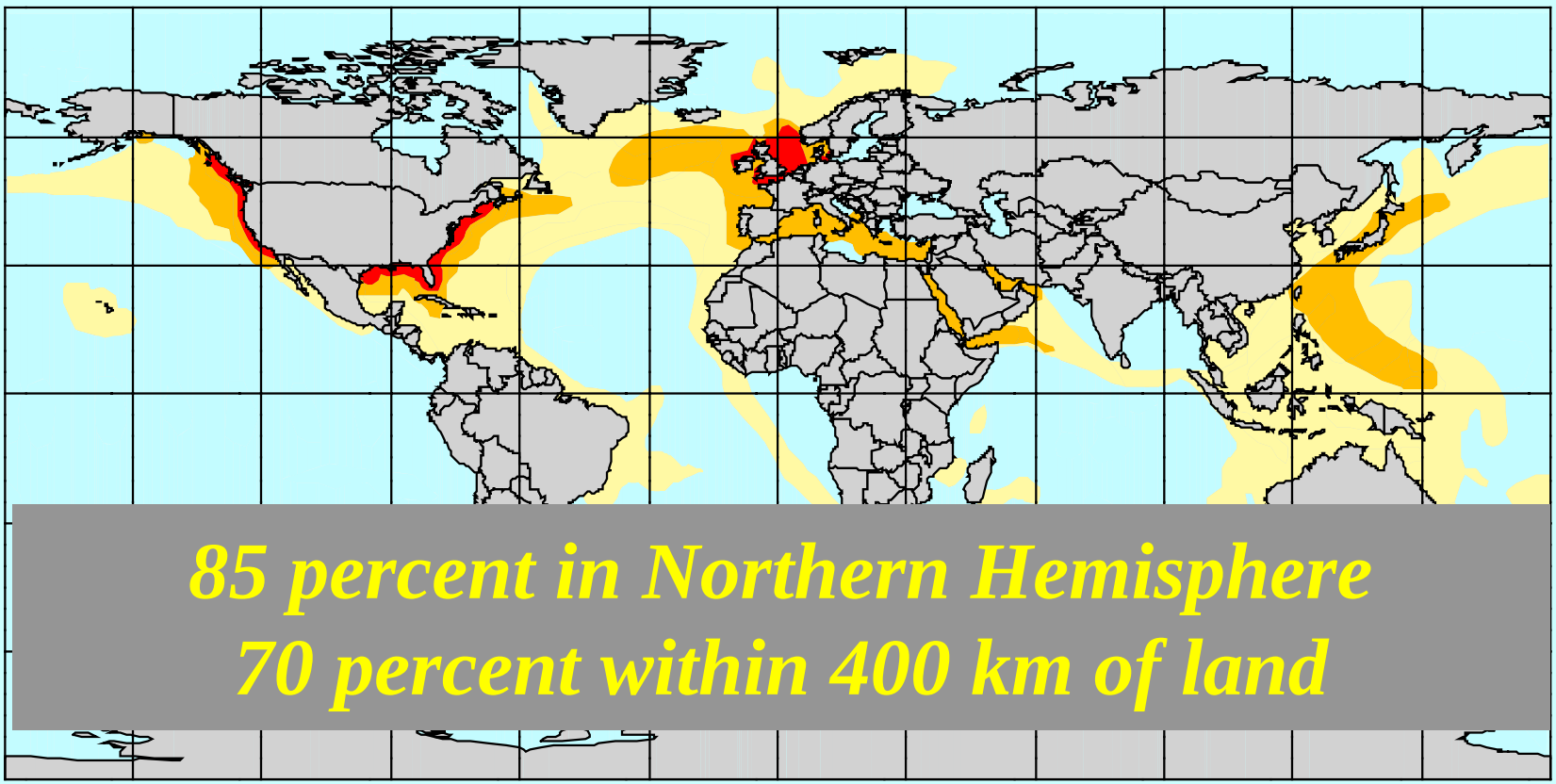
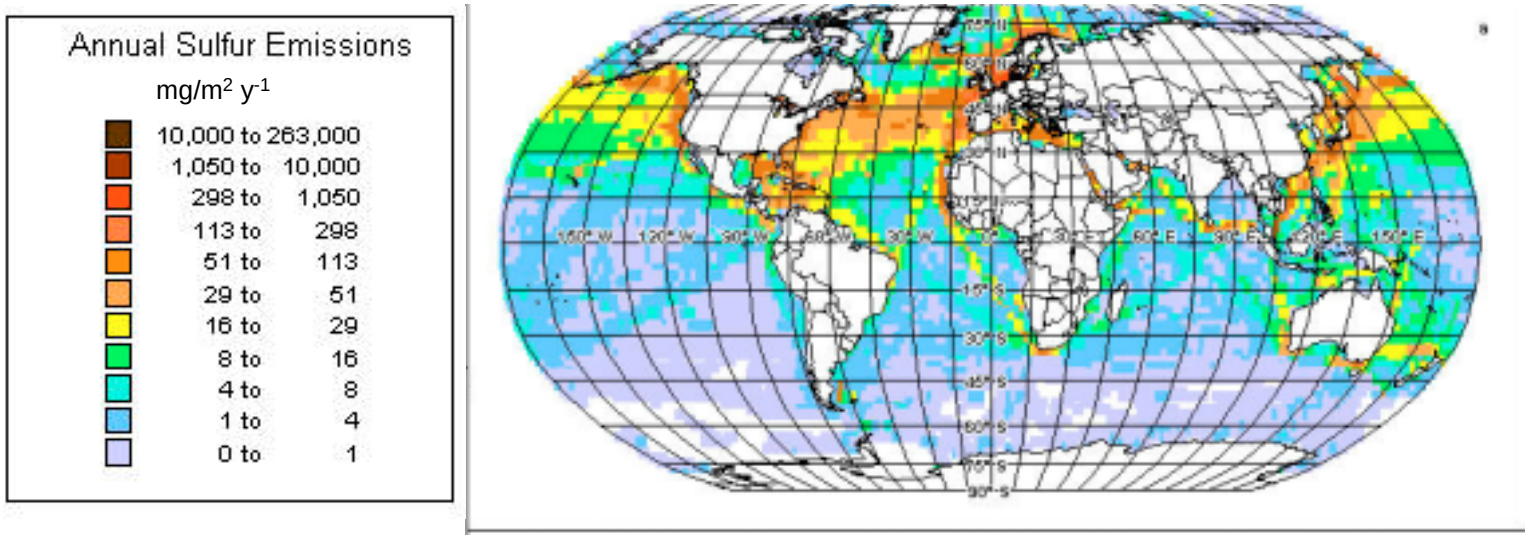
Global ship traffic density

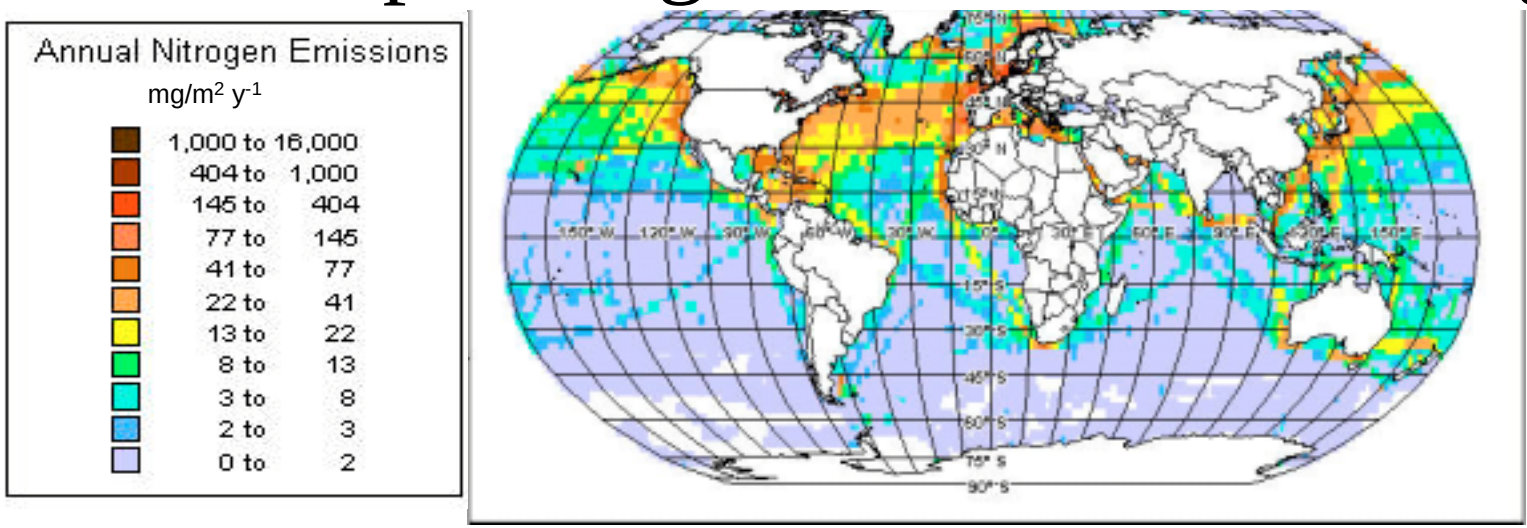


Source: IMO Study on Greenhouse Gas Emissions from Ships, MEPC 45(8), 2000.

Global Ship Sulfur Emissions: 4.24 Tg/yr



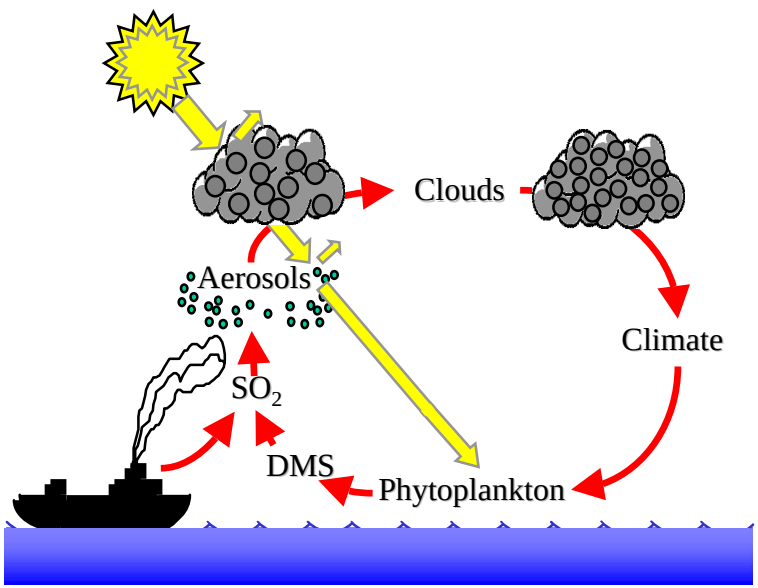
Global Ship Nitrogen Emissions: 3.08 Tg/yr



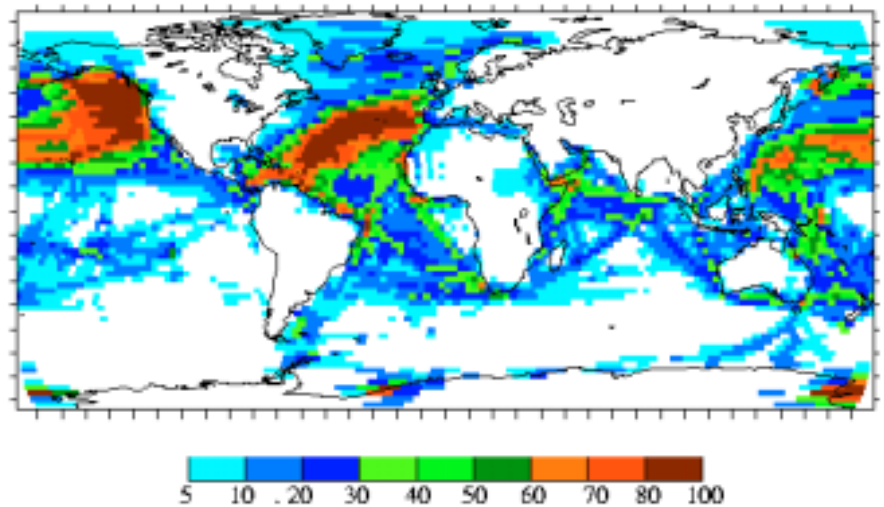
Source: Corbett and Fischbeck, JGR, 1999

Impacts:

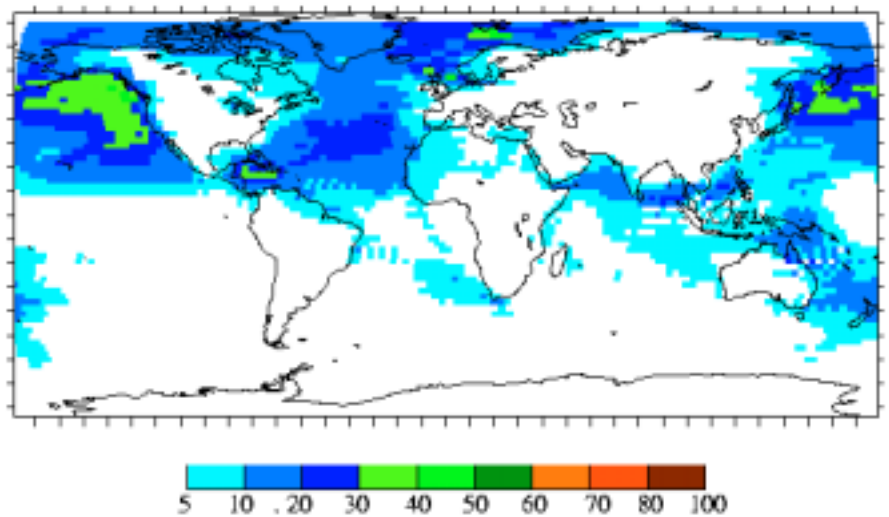
- Many coastal regions could consider international shipping as a source of background sulfate aerosol
  - Japan
  - Caribbean
  - Indonesia
  - West Coast US
  - New Zealand
  - Scandinavia



% SO_2 from ships

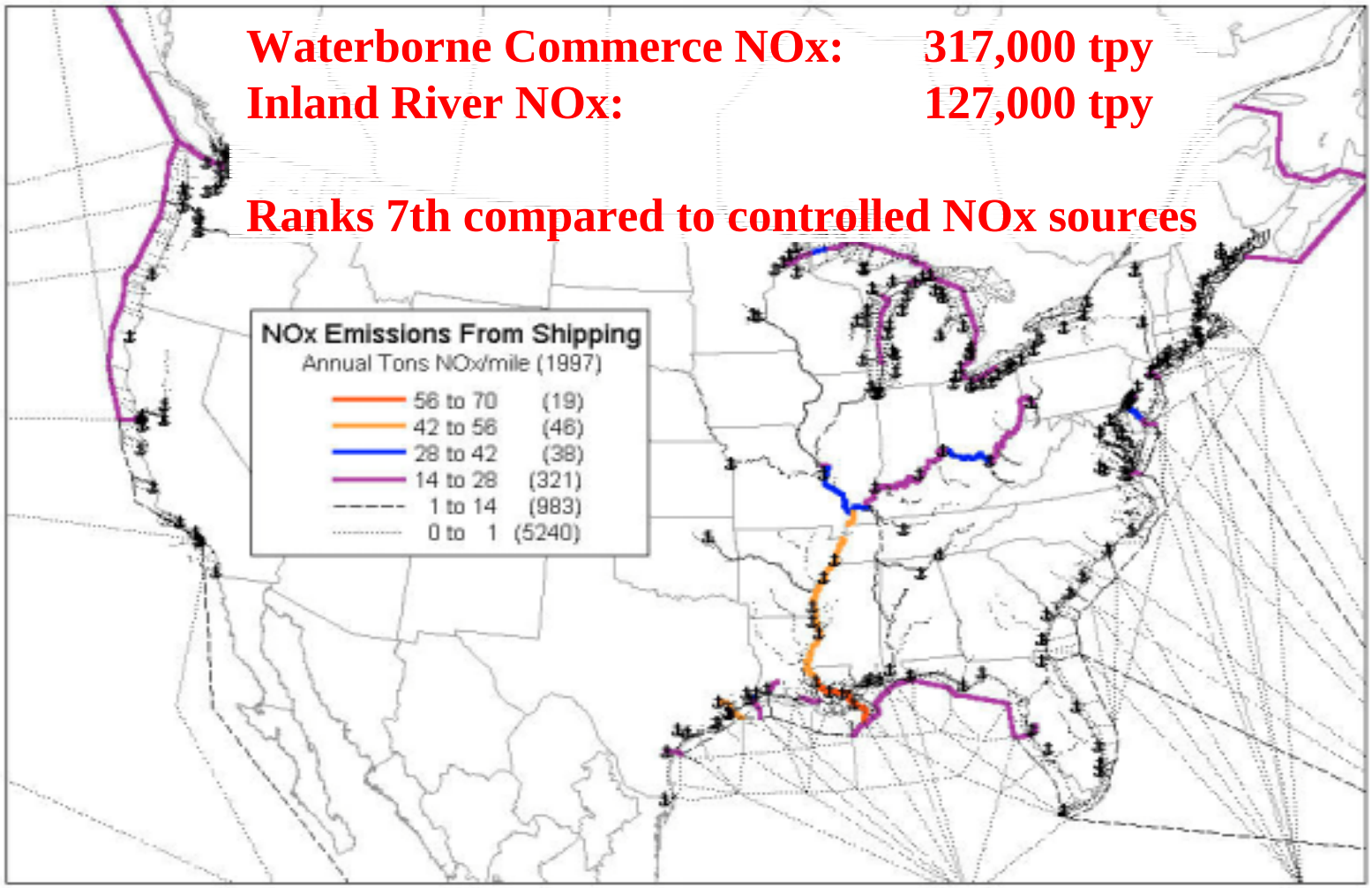


% sulfate from ships



Source: Capaldo, K.P., et al., Nature, 1999.

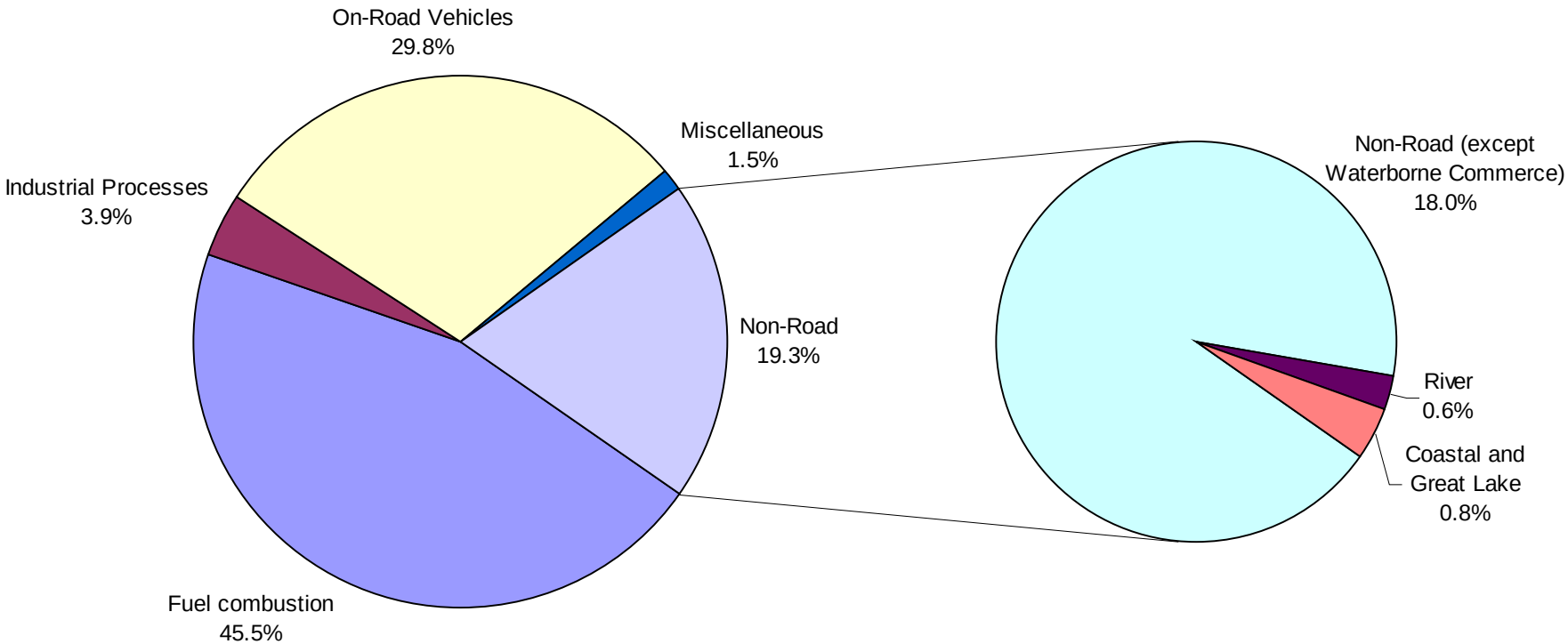
NO_X Emissions From US Ships



Source: J. Corbett and P. Fischbeck, ES&T, 2000

National NOx Emissions Estimates (U.S. EPA) with Waterborne Commerce Emissions (Corbett and Fischbeck, 2000) Shown as a Part of Non-Road Vehicles Category Category

Total NOx in 1997: 23.6 million tons



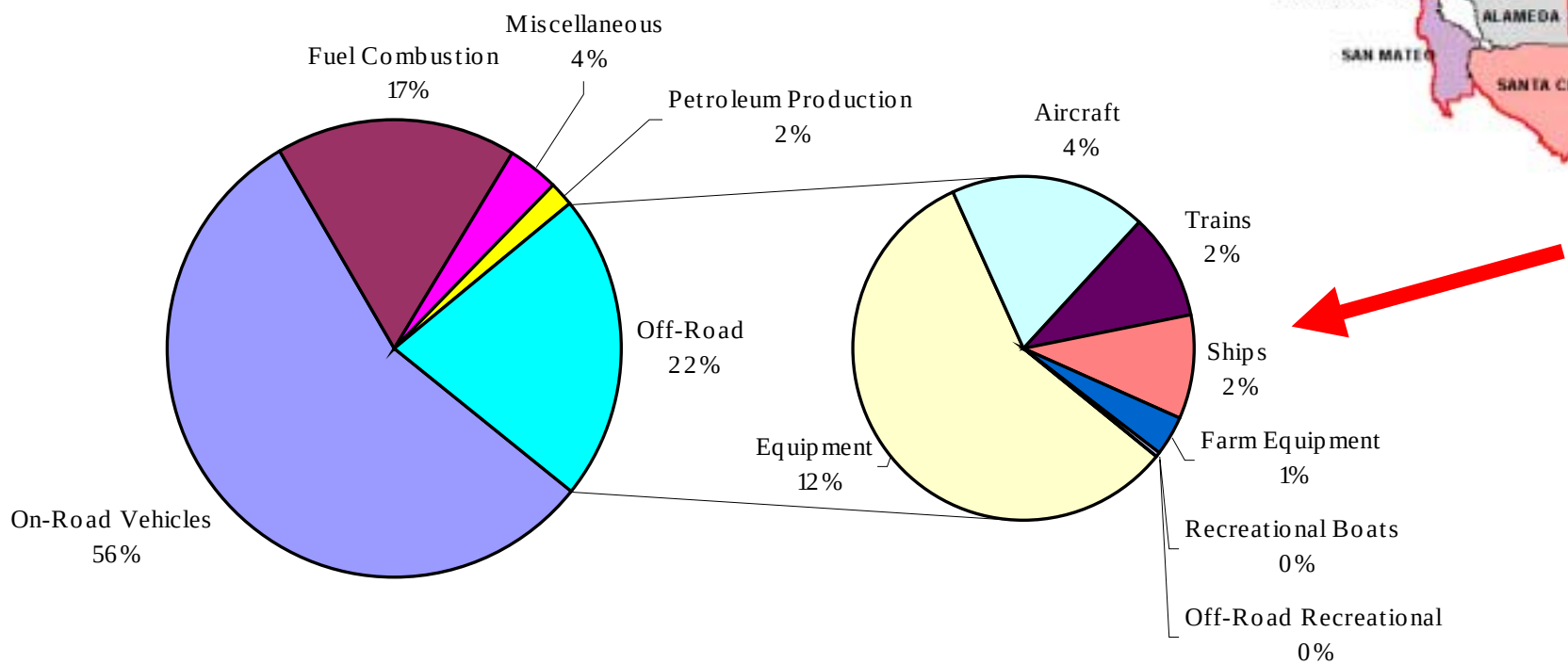
Source: J. Corbett and P. Fischbeck, ES&T, 2000

Ships appear in current inventories...

NOx Emissions by Category
San Francisco Bay Area Air Basin

Source: CARB, http://www.arb.ca.gov/emisinv/maps/basins/absfmap.htm

1996 Total NOx = 539 Tons per day



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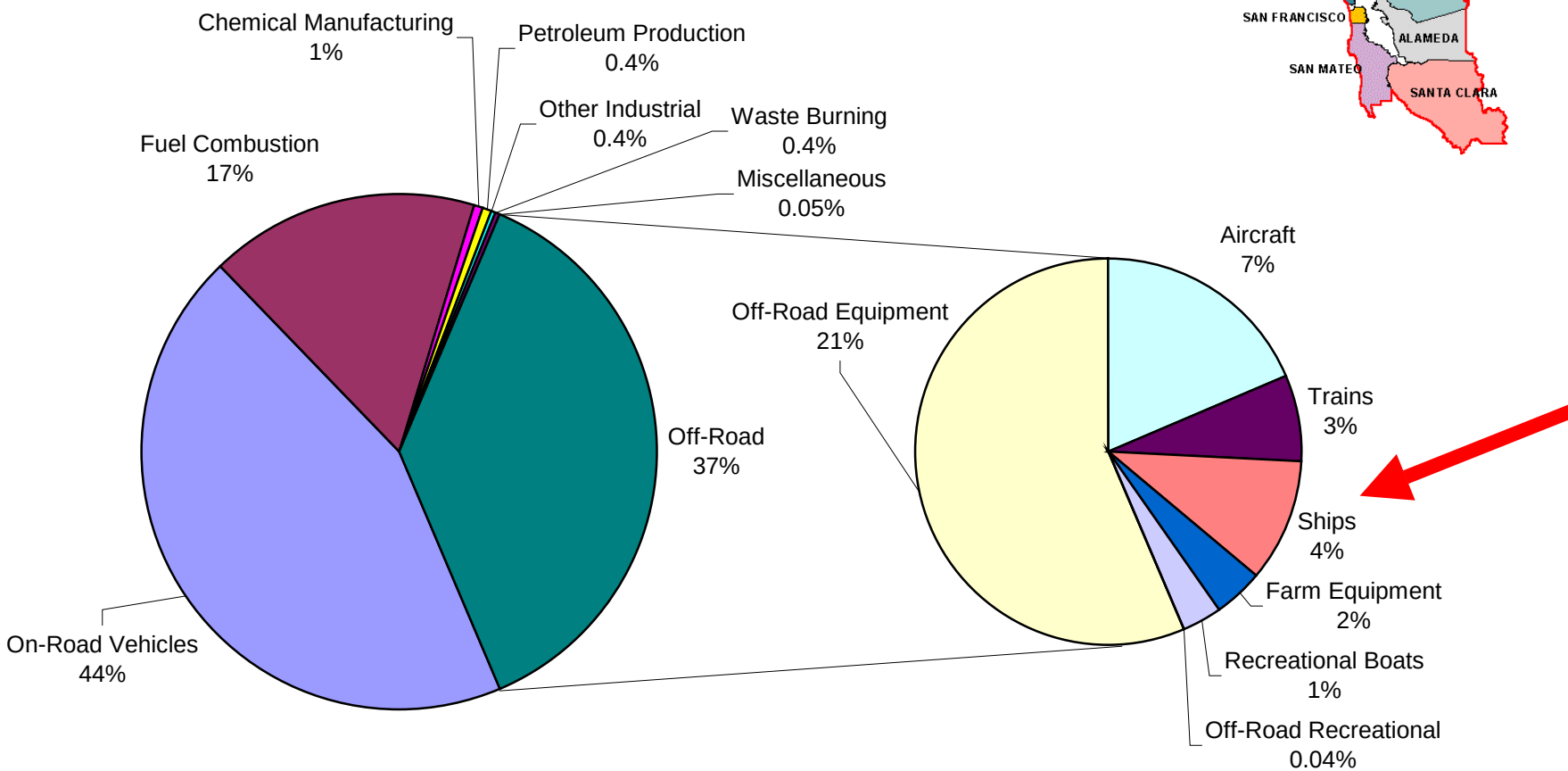
…and projected to become larger fraction

Projected 2010 NOx Emissions by Category
San Francisco Bay Area Air Basin

Annual Average NOx = 387 Tons per day

Source: CARB, 2000

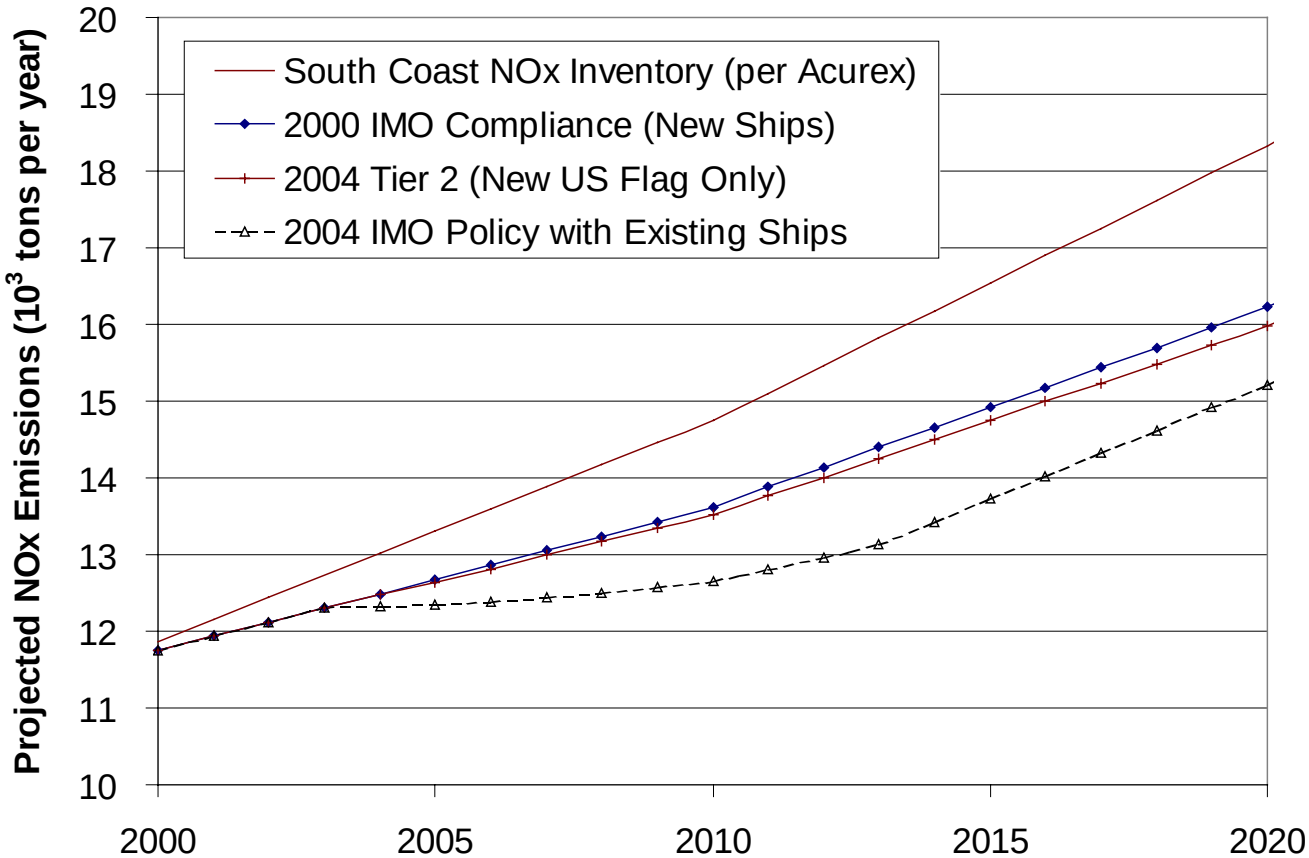


Source: J. Corbett and A. Farrell, under review.

Current MTS Trends

- Overarching trend: globalization and integration of transportation systems
- Modernization and expansion
  - Trade growth
- Multiple constraints and policy issues
  - Ship air pollution only newest issue for industry
- Industry and government (DOT, MARAD) increased partnering to promote U.S. fleet
  - U.S. opportunity to be proactive, not left behind
- Multi-jurisdictional nature of shipping will encourage market-based policies

San Pedro Bay NOx Emissions from Oceangoing Ships



Bottom line: Extending U.S. EPA regulations to large engines is little better than IMO Policy, but international standards for existing engines can have more local impact

Source: J. Corbett, 1999

Opportunities to Reduce Emissions

- Short-term: Operational measures, limited potential
  - IMO study showed potential for slower speeds to reduce emissions
  - Being tried in Southern California under voluntary plan
- Near-term: After-treatment retrofits, cleaner diesels
  - This is being done in Europe, demonstration projects in U.S.
  - Trade-offs?
- Long-term: Alternative fuels for diesels, advanced engine technologies, alternative propulsion
  - Need for demonstration projects, policy incentives

Navigating the Way Ahead: Policy Mechanisms

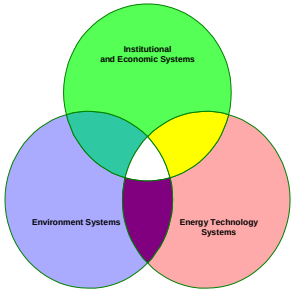
- Traditional policy picture
  - complex, multi-jurisdictional, international
- Market-based opportunities
  - Win-win potential more rapid than regulation
  - Supports modernization, sustainable growth
- Possible Kyoto Protocol connections
  - Clean Development Mechanism (CDM)
  - Emissions trading

Are vessels important component of total emissions from Port Activity?

- POHA landside NOx emissions roughly equal to towboat emissions
- However, this varies greatly by cargo type:
  - Containerized and general cargoes landside versus OGV roughly equal
  - Liquid bulk landside much lower (8-16 times) than OGV due to electric pumps for cargo transfer
    - assumes vessel cargo pumps are counted on waterside
  - Depends on how far out transit emissions are included, speeds of transit, and the nature of cargo handling technology (direct to rail versus indirect yard movements)
- Future regulatory trends will reduce landside faster than waterside emissions under current policy framework

Traditional Pollutants and Regulatory Trends:

- International standards for new marine engines send a *clear regulatory signal*
- National and multinational regional air quality will continue to impose *more stringent standards*
  - U.S. EPA regulations, Baltic and North Sea Special Area designation, Sweden's Market-based Approach
- *State and local requirements* to meet clean air standards will continue to focus regulatory action
  - address existing engines through retrofit standards, emissions trading incentives, and operational requirements



MTS and Environment:
Concluding Policy Thoughts

- GLOBAL: Consider the system dynamics
  - Port capacity, intermodal distribution, trade growth
  - Market solutions can be catalyst for improvement
- CLIMATE: Look for Win-Win opportunities
  - Trade-off between GHGs, traditional air pollutants
  - In MTS, link fuel-economy and clean technologies
- CHANGE: Facilitate demonstration projects
  - Use modernization goals to support lead adopters
  - Include MTS in long-term transportation R&D